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Original empirical article

EVALUATION OF LEARNING ROWING TECHNIQUE IN A TWELVE-OARED SCHOOL BOAT GALLEY *

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Abstract. *This study investigated the effects of learning a rowing technique in a twelve-oared school boat galley on variables of the stroke. The study included 44 students of the Faculty of Sport and Physical Education of Belgrade University, with no previous rowing experience (aged 25.34±1.95; weight 81±8kg; height 184±7cm). The subjects learned an elementary rowing technique in a twelve-oared school boat galley. The practice sessions were conducted according to the basic rowing technique program, three times a week over a ten-week period. The CONCEPT II rowing ergometer was used for collecting data on the initial and final tests. Stroke variables in real time were measured by WEBA Sport's FITRO ROWER. The subjects received no instructions as to the use of specific force distribution and stroke length. Thirteen biomechanical variables of the stroke were measured, including temporal variables, variables of force and power, velocity variables and a spatial variable. The test consisted of three consecutive 30s measurements at an assigned rowing frequency of 24, 28 and 32str/min, respectively. As expected, significant changes were noted in all of the measured variables. The results of the final measurement showed that subjects properly learned the stroke length. The greatest progress in the absolute values and the greatest decrease in the variation coefficient were noted in the power and force variables. Significant changes in all of the measured variables and the decrease of the variation coefficient were noted with the increase in rowing frequency. The frequency of rowing was proven to be an important factor in acquiring rowing technique. Therefore, learning should start at low frequency, and soon increase to the frequency of 32str/min. The results confirmed that the faults in rowing technique can be evaluated on the basis of the variability of the tested stroke variables.*

Key words: *WEBA, CONCEPT II, frequency, force, stroke length.*

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1. INTRODUCTION

There has been an increasing interest in the sport of rowing over the past few decades. Besides sports rowing, this kind of physical activity has been included in fitness programs, rehabilitation programs and physical education curriculums. Earlier investigations showed that besides rowing training, rowing ergometry could be an effective alternative activity used for the purposes of physical fitness (Hagerman et al., 1988), cardio respiratory system rehabilitation programs (Buckley et al., 1999; Urhausen et al., 1994) and rehabilitation after injuries (Hagerman et al., 1988). On the other hand, an inadequate rowing technique can lead to injuries, including musculoskeletal problems in the lower back, ribs, shoulders, wrist and knees (Hickey et al., 1997; Karlson, 2000; McGregor et al., 2002; Rumball et al., 2005). Considering the rifeness of rowing and the possible disadvantages of rowing, the changes in rowing technique in the initial stages of rowing practice seem to be important for investigation. Additionally, technical development is one of three crucial and inter-related aspects of training that require equal attention, the other two being physical and mental development.

The mutual influence of the theory and practice of learning rowing technique produced diverse methodical concepts over time. Depending on the goals of teaching, trainers' preferences and the available equipment, different teaching aids are used, such as rowing in a twelve-oared school boat g*alley*, rowing tanks, group boats (8+, 4X, 4+, 2+, 2X, 2-), rowing ergometers, sculls (1X) and others. Traditionally, the group approach to learning the rowing technique in stable boats is also used in special physical education of the military, police force, rescue units, lifeguards, and the crews of tourist and merchant ships. The group approach is equally important for use in classes for novice rowers provided within the scope of the tourist industry and children's camps.

Numerous studies have indicated the importance of monitoring the changes taking place in the process of learning the rowing technique or training elite rowers. Rowing involves the conversion of muscular forces translocated through complex movement patterns that utilize all the major muscle joints in the body. High performance rowing depends on skill and precise timing in which all movements have purpose and function. Hence, it is possible to characterize the grade of the acquired rowing technique through the major kinetics and kinematic variables such as force production, drive length, duration of the rowing cycle, etc. While investigating the learning process of the rowing technique, researchers focused on the adaptation of dependent biomechanical variables outcome through motor learning tasks (Sparrow et al., 1999).

Recent research interest was directed at evaluating the characteristics of the movement pattern that is characteristic of well-trained individuals (Newell and Corcos, 1993; Schoner et al., 1992; Zanone and Kelso, 1994).

Earlier research showed that one of the characteristics of learning high power-demanding skills, such as rowing, is the increase in impulse per cycle, maximizing power output (Van Soest and Casius, 2000), or increasing propulsive power output per kilogram of body mass (Smith and Spinks, 1995). Also, specific modifications of the movement pattern with practice were associated with changes of the length of the drive phase and the duration of the rowing cycle (drive and recovery phases) (Sparrow et al., 1999). Practice may also lead to reduced variability in impulse control, since in the previous studies the standard deviation of the impulse per stroke also declined with practice (Sparrow and Newell 1994; Sparrow et al., 1999). One characteristic of motor performance that has received widespread interest in recent research is the consistency or stability of movement patterns during motor learning (Anderson et al., 2005).

In sport rowing, contractile and oxidative characteristics limit the rowers' physical abilities. Critical frequencies were defined depending on the types of boats and individual differences between rowers (Celentano et al., 1974; Redgrave, 1995). Empirical attempts were made to define the frequency ranges which could be used in competitions (Zatsiorsky and Yakunin, 1991), and/or assigned to individuals to improve specific rowing skills (Nilsen, 2001). Correlations between zones of training (pulse) and rowing frequencies were defined in different ways over time. Assigned frequency became a compulsory element in setting training intensity.

The purpose of the article is to present the most relevant effects of learning rowing technique on the tested biomechanical variables. The intention of the authors was to evaluate the effects of a standard teaching program, namely rowing in a twelve-oared school boat *galley*.

It was hypothesized that more stable control with practice would be reflected in the reductions of movement pattern variability and significant changes of the absolute values of observed biomechanical variables. The experiment was also an opportunity to investigate the influence of assigned rowing frequencies on biomechanical variables of the stroke during different learning phases.

2. METHODS

2.1. Sample of participants

The participants in the study were students of the Faculty of Sport and Physical Education of Belgrade, who had no previous rowing experience. The study included an experimental and control group consisting of 44 male students (aged 25.34±1.95; weight 81±8 kg; height 184±7) and 30 male students (aged 22±2.2; weight 75.3±4; height 183.3±7.22), respectively. Informed consent to participate in the study was obtained in accordance with the procedures approved by the Faculty Research Ethics Committee.

2.2. Experimental Procedure

The initial measurements were made immediately after the instructions were given to the participants. The procedures for initial and final measurements were identical. Test administration, equipment and subject preparation complied with the rules and advice from the rower testing protocols (Hahn et al., 2000).

The participants received no instructions as to the force distribution or stroke length. The test included 3 rounds of measurement, each of which lasted for 30 seconds, at the assigned rowing frequencies of 24, 28 and 32 str/min, respectively. For control of the assigned variables, the technique of counterbalance was used with six possible disposals.

In the experimental and empirical sources, the reported stroke frequencies ranged between 18 and 50 str/min, either as assigned values or as results obtained irrespective of the instructions and mechanical conditions of the performance (Celentano et al., 1974; Lisiecki and Rychlewski, 1986; Redgrave, 1995; Sanderson and Martindale, 1986; Zatsiorsky and Yakunin, 1991). Stroke frequencies were reported to range between 34 and 50 str/min at regattas, and between 22 and 34 str/min during the learning process for the rowing technique. As a result, the assigned frequencies ranged between 24 and 32 str/min. The strategy to use three representative frequencies was based on an attempt to achieve motor output discrimination in that frequency scale.

The participants performed 10 to 15 strokes in 30 seconds. The duration of each round was a compromise between a sufficient number of strokes and the influence of factors disrupting the stability of the technique, such as tiredness, poor physical preparedness and the influence of psychological factors, including concentration, motivation and others. The interval between the trials lasted for 15 - 20 seconds. During the measurements, one of the two measurers stood beside a participant and registered the entry into the regime of the assigned frequency, whereas the other, when signaled by the former, recorded biomechanical variables on the computer. Stroke parameters were measured only after the participants achieved the assigned stroke frequency and managed to maintain it at a constant level.

Final measurements were made immediately after the end of the practice sessions.

2.3. Practice sessions

In the next step, the participants were taught the rowing technique in a twelve-oared school boat *galley*. A *galley* is a frequently used, wide, stable school boat with twelve sliding seats and foot stretchers (6 seats in each row) and oars connected to the boat using rigger similar to that in racing boats. The length of a flat bottomed g*alley* is 12m, max width 1,4m, and weight without the crew is 585kg. Overall weight could reach approximately 1800kg with 12 rowers and 3 coaches inside (15x 80kg=1200kg). The depth of immersion calculated by the previous weight of the complete boat and crew is 0,17m.

Efficiency of motor learning in the *galley* was achieved by the supervision of all the participants and error correction by one instructor. Such group work had advantages over individual work as it was an opportunity for the participants to compare the way they perform the rowing technique. The structure of the *galley* was such that it provided safety and stability to the crew, not allowing waves and the wind to spoil the classes. It should be noted that the *galley* was used as a discrete learning instrument and only during the initial stage of acquiring the rowing technique, which enabled one to explore the specificities of the instrument. Upon the completion of a 30-lesson course in the *galley*, trainers typically start using a number of different learning instruments, while rowers continue to practice until their rowing skills have become partly “automatic”.

The practice sessions were conducted three times a week over a ten-week period, as part of a rowing course taking place during the summer term at the Faculty of Sports and Physical Education. During the early stages of acquiring these skills, especially the skills involving multiple degrees of freedom, the coordination and control of movement are complex and difficult to organize. It has been suggested that the learner “freezes” biomechanical degrees of freedom early in the practice by keeping either a single segment or limb segments fixed and then releasing the constraint on the joint movements over time (Vereijken et al., 1992).

During the first twenty sessions, the rowers mostly worked on stroke parts and sequences, whereas from session 21, they combined isolated stroke parts and sequences into continuous rowing. Throughout the rowing course, a combined method of learning was used, including practicing continuous rowing and stroke parts; the occasional focusing of attention on individual technical elements; slow demonstrations and repetitions while keeping specific positions for emphasis. The learning method and learning instrument that were used made it possible to apply the principles of motor learning. Additionally, the subjects, who were physically active, were not expected to show responses to the relatively low work demands in the experiment.

The control group participated in no activities connected to rowing between the pre and post test.

2.4. Apparatus

To gather data (on the initial and final tests), the CONCEPT II rowing ergometer was used. For more than three decades, rowing ergometers have seen an increasing and ever more justified use in the training and testing of rowers (Hahn et al., 2000). A high correlation between regular rowing and the CONCEPT II rowing ergometer was noted (Lamb, 1989). This particular ergometer has been shown to have certain advantages in measuring biomechanical stroke variables (Steer et al., 2006; Nowicky et al., 2005).

Stroke variables in real time were measured by WEBA SPORT's FITRO ROWER, which was connected to a computer via a probe. Ergometer resistance was achieved by rolling the wheel with built-in spades, with the increase in resistance growing exponentially, which corresponded to water resistance (Lamb, 1989). Airflow to the spades was controlled by regulating the bar, and it was set at a standard value of 5. The displaying and processing of the data were enabled by WEBA Sport's SOFTWARE EXPERT 1.2 software package (Group of authors, 2003). Fitro Rower is designed to measure time, force and stroke length. All the other variables were calculated using generally accepted formulae. Time was measured by an automatic timer to the one-hundredth of a second. The position and the length of handle movement were established and measured by the rowers' moving a chain over an optical coupling device recorded to the nearest 0.1cm. An electronic force-measuring probe was attached to a system of wheels driven by the chain. In the probe, force was transformed into an electrical signal that could be read from the computer screen. The force measure range was from 0N to 500N, with 10-bit conversion.

Thirteen different biomechanical variables of the stroke were measured, and in particular drive time **ACT TIME** (m/s), recovery time **PAS TIME** (m/s), rhythm (active stroke phase duration to passive stroke phase duration ratio) **RAT** (%), attained rowing frequency **FRQ** (stroke/min), power average during the stroke cycle **POW AVRt** (W), power average during the drive time **POW AVRa** (W), power peak **POW PEAK** (W), force average during the stroke cycle **FOR AVRt** (N), force average during the drive time **FOR AVRa** (N), force peak **FOR PEAK** (N), handle velocity average **SPEED AVRa** (m/s), handle velocity peak **SPEED PEAK** (m/s) and the length of handle movement **STR LENGTH** (cm).

2.5. Statistical Analysis

Only complete strokes in each of the participants were taken into account. Depending on the assigned frequency, between 10 and 15 strokes were included in the computation of average values for each variable, which represented a sufficient sample for every subject. The arithmetic mean values of all the participants were used to calculate the arithmetic mean value, standard deviation and variation coefficient for whole group, and the T-test for dependent samples was used to determine the influence of learning rowing technique on biomechanical variables of strokes.

3. Results

3.1. Experimental Group

The results of the T-test indicated a statistically significant difference between the values registered during the initial and final measurements, in all the variables and at all three levels of rowing frequency.

Under the influence of practice sessions, ACT TIME decreased significantly, PAS TIME increased significantly, and RAT decreased significantly, at each of the three assigned frequencies (*Table 1*).

Table 1. Absolute values, results of the T-test and the significance of the initial and final measuring at the three assigned stroke frequencies for temporal variables

Active time ACT TIME									
	24 str/min			28 str/min			32 str/min		
Measuring	Absolute values (ms)	T test	Sig (p<…)	Absolute values (ms)	T test	Sig (p<…)	Absolute values (ms)	T test	Sig (p<…)
Initial	1274,8	6,483	0,01	1126,4	5,968	0,01	1006,6	2,969	0,01
Final	1179,2			1067,4			987,9		
Passive time PAS TIME									
	24 str/min			28 str/min			32 str/min		
Measuring	Absolute values (ms)	T test	Sig (p<…)	Absolute values (ms)	T test	Sig (p<…)	Absolute values (ms)	T test	Sig (p<…)
Initial	1164,7	-7,224	0,01	1016,5	-7,258	0,01	886,4	-2,18	0,05
Final	1293,4			1096,5			903,6		
Rhythm RAT									
	24 str/min			28 str/min			32 str/min		
Measuring	Absolute values (ms)	T test	Sig (p<…)	Absolute values (ms)	T test	Sig (p<…)	Absolute values (ms)	T test	Sig (p<…)
Initial	110,31	8,275	0,01	111,74	7,086	0,01	114,47	3,075	0,01
Final	92,85			98,37			110,2		

An increase in the FRQ led to the decrease in the ACT TIME and PAS TIME, and the increase in RAT (*Table 1*). Under the influence of the practice sessions, ACT TIME to the ACT TIME + PAS TIME ratio went down. Increase in the FRQ during the final measurement resulted in the increase of the abovementioned ratio (*Table 2*).

Table 2. Duration of drive time to duration of complete stroke ratio at the three assigned frequencies in the initial and final measuring

Duration of drive time to duration of complete stroke ratio			
Measuring	24 str/min	28 str/min	32 str/min
Initial	0,52	0,53	0,53
Final	0,48	0,49	0,52

The results for FRQ during the initial and final measurements show that the participants successfully performed the assignments (*Table 3*). The smallest deviation from the assigned frequency was noted at the frequency of 28 str/min.

Table 3. Attained stroke frequencies at the initial and final measuring

Attained stroke frequency FRQ									
	24 str/min			28 str/min			32 str/min		
Measuring	Absolute values (str/min)	T test	Sig (p<…)	Absolute values (str/min)	T test	Sig (p<…)	Absolute values (str/min)	T test	Sig (p<…)
Initial	24,64	2,026	0,05	28,06	3,431	0,01	31,74	-0,43	0,996
Final	24,31			27,77			31,74		

Learning the rowing technique has a significant impact on the increase in the variables of power and force, namely POW AVRt, POW AVRa, POW PEAK (*Table 4*), FOR AVRt, FOR AVRa and FOR PEAK (*Table 5*). Increase in the FRQ led to the increase in all the stroke variables of power and force.

Table 4. Absolute values, results of the T-test and the significance of the initial and final measuring at the three assigned stroke frequencies for power variables

Average power during entire stroke POWAVRt									
	24 str/min			28 str/min			32 str/min		
Measuring	Absolute values (W)	T test	Sig (p<…)	Absolute values (W)	T test	Sig (p<…)	Absolute values (W)	T test	Sig (p<…)
Initial	6,45	-7,058	0,01	23,78	-9,633	0,01	65,66	-9,408	0,01
Final	57,91			100,01			147,38		
Average power during the active phase POWAVRa									
	24 str/min			28 str/min			32 str/min		
Measuring	Absolute values (W)	T test	Sig (p<…)	Absolute values (W)	T test	Sig (p<…)	Absolute values (W)	T test	Sig (p<…)
Initial	12,92	-6,691	0,01	46,74	-9,083	0,01	124,89	-9,348	0,01
Final	129,63			208,29			283,93		
Maximum power POW PEAK									
	24 str/min			28 str/min			32 str/min		
Measuring	Absolute values (W)	T test	Sig (p<…)	Absolute values (W)	T test	Sig (p<…)	Absolute values (W)	T test	Sig (p<…)
Initial	53,85	-8,095	0,01	174,72	-10,512	0,01	418,45	-9,46	0,01
Final	409,38			637,65			878,8		

The greatest increase in the stroke power was noted at the assigned frequency of 24 str/min, and the least at the assigned frequency of 32 str/min (*Table 5*).

Table 5. Absolute values, results of the T-test and significance of initial and final measuring at the three assigned stroke frequencies for force variables

Average force during entire stroke FOR AVRt									
	24 str/min			28 str/min			32 str/min		
Measuring	Absolute values (N)	T test	Sig (p<…)	Absolute values (N)	T test	Sig (p<…)	Absolute values (N)	T test	Sig (p<…)
Initial	4,06	-7,982	0,01	14,06	-10,764	0,01	34,58	-9,46	0,01
Final	32,72			52,13			71,45		
Average force during the active phase FOR AVRa									
	24 str/min			28 str/min			32 str/min		
Measuring	Absolute values (N)	T test	Sig (p<…)	Absolute values (N)	T test	Sig (p<…)	Absolute values (N)	T test	Sig (p<…)
Initial	8,14	-7,536	0,01	27,61	-10,19	0,01	65,75	-9,419	0,01
Final	72,87			108,27			137,57		
Maximum force FOR PEAK									
	24 str/min			28 str/min			32 str/min		
Measuring	Absolute values (N)	T test	Sig (p<…)	Absolute values (N)	T test	Sig (p<…)	Absolute values (N)	T test	Sig (p<…)
Initial	34,25	-9,279	0,01	102,96	-11,421	0,01	221,72	-9,135	0,01
Final	230,32			329,53			423,27		

The average force during the active phase to maximum force ratio (*Table 6*) increased under the influence of learning the rowing technique. The greatest improvement between the two measurements was observed for the lowest assigned rowing frequency, whereas the least improvement was made at the highest one. Also, increase in this ratio was noted to follow the increase in the assigned rowing frequency.

Table 6. Average force during active the phase to maximum force ratio at the three assigned frequencies at the initial and final measuring

Average force during active phase to maximum force ratio			
Measurement	24 str/min	28 str/min	32 str/min
Initial	0,238	0,268	0,297
Final	0,316	0,329	0,325

Practice sessions significantly affected the increase in the values of SPEED AVRa and SPEED PEAK at all three levels of assigned rowing frequency (*Table 7*). The biggest increase in velocity was observed at the lowest assigned frequency, while the smallest increase was observed at the highest one. The increase in the FRQ resulted in the increased values of SPEED AVRa and SPEED PEAK (*Table 7*).

Table 7. Absolute values, the results of the T-test and the significance of the initial and final measuring at the three assigned stroke frequencies for velocity variables

Average handle velocity during the active phase SPEED AVRa									
	24 str/min			28 str/min			32 str/min		
Measuring	Absolute values (m/s)	T test	Sig (p<…)	Absolute values (m/s)	T test	Sig (p<…)	Absolute values (m/s)	T test	Sig (p<…)
Initial Final	1,022 1,376	-11,616	0,01	1,217 1,56	-10,926	0,01	1,438 1,701	-8,699	0,01
Maximum handle velocity SPEED PEAK									
	24 str/min			28 str/min			32 str/min		
Measuring	Absolute values (m/s)	T test	Sig (p<…)	Absolute values (m/s)	T test	Sig (p<…)	Absolute values (m/s)	T test	Sig (p<…)
Initial Final	1,31 1,842	-11,69	0,01	1,566 2,076	-11,514	0,01	1,885 2,278	-8,556	0,01

The results from the initial and final measurements show that the increase in STR LENGTH (*Table 8*) was statistically significant at each of the three assigned rowing frequencies. The biggest increase was observed at the lowest rowing frequency and the smallest at the highest assigned frequency. STR LENGTH increased with the increase of assigned frequency.

Table 8. Absolute values, results of the T-test and the significance of the initial and final measuring at the three assigned stroke frequencies for spatial variable

Length of handle movement STR LENGTH									
	24 str/min			28 str/min			32 str/min		
Measuring	Absolute values (cm)	T test	Sig (p<…)	Absolute values (cm)	T test	Sig (p<…)	Absolute values (cm)	T test	Sig (p<…)
Initial Final	130 161,2	-9,222	0,01	136,9 165,9	-8,831	0,01	144,6 167,7	-8,105	0,01

The results of previous studies show that the errors in rowing technique should not be discussed only on the basis of departure of the absolute values from a given model, but that the attention should be paid to the variability of stroke variables (Sparrow et al., 1999).

Table 9. Variability of the tested stroke variables at the three assigned frequencies at the initial and final measuring

Variables	Variability of the tested stroke variables					
	24 strokes/min		28 strokes/min		32 strokes/min	
	Initial	Final	Initial	Final	Initial	Final
ACT TIME	0,062	0,082	0,044	0,063	0,044	0,051
PAS TIME	0,061	0,092	0,057	0,072	0,059	0,057
RAT	0,103	0,167	0,093	1,31	0,097	0,105
FRQ	0,034	0,027	0,018	0,02	0,019	0,019
POW AVRt	2,295	0,828	1,261	0,565	0,873	0,355
POW AVRa	2,32	0,886	1,306	0,606	0,889	0,369
POW PEAK	1,999	0,73	1,228	0,5	0,821	0,341
FOR AVRt	2,144	0,726	1,183	0,477	0,782	0,295
FOR AVRa	2,176	0,78	1,221	0,515	0,796	0,309
FOR PEAK	1,873	0,634	1,141	0,421	0,727	0,287
SPEED AVRa	0,208	0,116	0,199	0,103	0,166	0,072
SPEED PEAK	0,213	0,142	0,208	0,113	0,181	0,081
STR LENGTH	0,205	0,1	0,195	0,099	0,169	0,082

The analysis of temporal variables (ACT TIME, PAS TIME, RAT and FRQ) has shown that their variation coefficient describes homogenous sets from the initial as well as the final measurement (*Table 9*). The analysis of the power and force variables (POW AVRt, POW AVRa, POW PEAK, FOR AVRt, FOR AVRa and FOR PEAK) has shown that their variation coefficients (*Table 9*) describe extremely non-homogenous sets at the initial measurement. Practice sessions seem to have primarily decreased the variation coefficients of the power and force variables at the final measurement compared to the initial one (*Table 9*). The assigned stroke frequencies seem to have had the greatest influence on the variation coefficients of the power and force variables (*Table 9*). The analysis of velocity variables (SPEED AVRa, SPEED PEAK) has shown that variation coefficients (*Table 9*) describe extremely homogenous sets for both the initial and final measurements. The spatial variable (STR LENGTH) in the context of the variation coefficient was in line with velocity variables (*Table 9*). Variability decreased at the final measurement in comparison to the initial measurement. The values of the final measurement describe extremely homogenous sets at each of the assigned rowing frequencies.

3.2. Control Group

The results of the T-test (*Table 10*) indicated the fact that there were no significant differences between the values registered at the initial and final measurements in most variables. The increased FRQ appears to have brought about the same changes to stroke variables in the control group (*Table 10*) as in the experimental group (*Tables 1 to 9*).

Table 10. Absolute values, results of the T-the test and significance of the initial and final measuring at the three assigned stroke frequencies for the stroke variables in the control group

Measuring	Control group								
	24 str/min			28 str/min			32 str/min		
	Absolute values (ms)	T test	Sig (p<...)	Absolute values (ms)	T test	Sig (p<...)	Absolute values (ms)	T test	Sig (p<...)
ACT TIME Initial	1196,5	-2,9	0,018	1086,3	-1,55	0,156	969,5	-1,43	0.188
ACT TIME Final	1277			1157,3			996,4		
PAS TIME Initial	1193,4	0,28	0,786	1057,4	-0,01	0,995	917,3	-1,11	0,294
PAS TIME Final	1186,6			1057,5			940,4		
RAT Initial	101,1	-1,88	0,093	103,8	-1,07	0,314	106,4	-0,29	0,775
RAT Final	108,3			110,6			107,1		
FRQ Initial	25,19	2,75	0,022	28,01	1,98	0,079	31,8	1,46	0,179
FRQ Final	24,49			27,2			31,1		
POW AVRt Initial	3,89	0,99	0,35	14,69	0,4	0,699	18,68	-1,68	0,128
POW AVRt Final	0,64			13,44			25,42		
POW AVRa Initial	7,8	0,99	0,349	30,71	0,52	0,616	36,56	-1,54	0,158
POW AVRa Final	1,22			26,83			48,96		
POW PEAK Initial	28,7	0,96	0,361	88,7	0,19	0,852	117,02	-1,87	0,094
POW PEAK Final	7,58			84,18			169,31		
FOR AVRt Initial	2,34	0,98	0,353	7,22	-0,25	0,981	9,12	-2	0,076
FOR AVRt Final	0,47			7,26			13,85		
FOR AVRa Initial	4,7	0,98	0,352	15,1	0,18	0,861	17,86	-1,9	0,091
FOR AVRa Final	0,89			14,49			26,69		
FOR PEAK Initial	16,66	0,94	0,372	42,91	-2,06	0,841	57,47	-2,18	0,058
FOR PEAK Final	5,46			45,44			93,6		
SPEED AVRa Initial	0,753	-3,8	0,712	0,9	-1,28	0,232	1,06	-2,08	0,067
SPEED AVRa Final	0,771			0,94			1,56		
SPEED PEAK Initial	0,963	-5,67	0,585	1,15	-1,29	0,229	1,35	-2,14	0,061
SPEED PEAK Final	0,998			1,2			1,47		
STR LENGTH Initial	89,79	-1,57	0,152	97,41	-1,87	0,094	103,06	3,037	0,014
STR LENGTH Final	98,26			108,04			115,74		

4. DISCUSSION

Changes in the absolute values of stroke variables and their variability were analyzed by groups including similar variables. The discussion starts with the temporal variables, followed by the variables of power and force, velocity-related variables and the spatial variable.

The results of this research correspond to the rules of stroke duration dependence on the assigned rowing frequency (Celentano et al., 1974). The high hydrodynamic resistance of the training boat affected stroke rhythm, which was higher than in racing boats due to the faster deceleration of the boat to a critical value at the point when a new stroke should begin in order to maintain the velocity of the boat. Beginners increased their rowing frequency by shortening the passive stroke phase, which indicates that rhythmical structures were not fully adopted or, in other words, that the time structure of muscle activation was poor. Practical experience has been confirmed that the recovery phase presents the rowers with a much greater chance to influence stroke rate than the drive phase (Nolte, 2005b).

It was observed in some studies (Kleshnev, 1995) that there was a significant correlation between the duration of drive time to a complete stroke ratio and propulsive efficiency ($r=-0.69$, $p<0.01$). Propulsive efficiency is connected with the hydrodynamics of the boat shell and oar blade, and estimated in the range of 60-80% of useful work per the quantity of energy input. This ratio is a significant factor for the evaluation of rowing technique. This ratio also shows that stroke efficiency increased due to practice sessions (*Table 2*). The above ratio showed that the participants rowed less efficiently with the increase of the assigned rowing frequency. From this point of view, it could mean that the learned technique improves only at lower rowing frequencies.

The assigned frequency was achieved to a large extent. It can, therefore, be concluded that the reported variables achieved on performing different tasks were not due to variations in the assigned frequencies.

The large improvement in the variables of power and force (*Tables 4 and 5*) under the influence of practice sessions confirms the findings of earlier studies (Smith and Spinks, 1995) that stroke power, as well as the force and power themselves (McNeely et al., 2005), are significant variables which distinguish elite rowers from beginners. Considerable increase in the values of power and force (*Tables 4 and 5*) in the final measurement in comparison to the initial measurement could, in some cases, be explained by the near unrealistically low initial values produced by the students, inexperienced novice rowers and also by the specific influence of practice sessions. High navigability, high water resistance and high inertness of the boat had a positive effect on learning the technique elements of power and force. Under the conditions of the heavy and slow boat, it is much better to establish contact between the spade of the oar and water during the drive phase; the possibility of the oar sliding is reduced, and the force required to move the boat is higher than with lighter and narrower boats, and there is higher possibility for high values of power and force to manifest themselves, taking into account the big surface of the boat base and stable position of the rowers in the boat.

The increase in power following the increase in the assigned rowing frequency (*Table 5*) in both the initial and final measurement was expected, as the power is directly proportional to the work done and reversely proportional to the time needed for the work to be done. The practical rule that beginners usually increase frequency and force simultaneously when asked to increase speed was confirmed. The results of this research correspond to the rules of dependence of the work done on the stroke frequency (Celentano et al., 1974). The increase in force following the increase in assigned rowing frequency at both the initial and final measurements was expected as the duration of the stroke does not hinder the achievement of high force values and it has a positive effect on the elasticity of muscle sinews in cyclic movements. Also, force is established faster under the influence of increased rowing frequency, partly because the muscles are continually in a fast transition from the stretch to shortening regime and this behavior makes the active phase of the stroke more powerful and effective (Ishikawa et al., 2005).

Previous studies compared the curves of pulling force in real time (Zatsiorsky and Yakunin, 1991). Two basic shapes are defined, namely a shape with a characteristic peak and a trapezoid shape. The main recommendations for improving the rowing technique are the increase in the level of average force and the average to maximal force ratio (Kleshnev, 1995). This ratio stands out as a significant factor in rowing technique evaluation. The closer this ratio is to 1 the closer is the curve in real time to the trapezoid shape. Also, boat velocity can be kept on the same level by changing only the way in which the force is manifested in real time (Sanderson and Martindale, 1986). A lower level of peak force is recommended, but also a longer retention of the assigned force level. In analyzing international-level rowing, it was determined that often increased boat velocity was accomplished by a greater application of force during the drive phase and, more importantly, the exertion of force over a greater percentage of the time for the stroke cycle (Martin and Bernfield, 1980). This is also supported by the surprising results of force measurements, as some rowers who accomplished lower force values had higher average boat velocities (Filter, 1997). Similar force-time profiles were expected to minimize turning moments on the boat that result from unequal forces. Also, the selection of crew members based on similarities in force-time profiles was described in earlier studies. Some researchers believe that profiles must be the same, and some believe that specialization regarding the specific seat in the boat is needed (McBride, 2005). The above dilemma emphasizes the importance of knowing and understanding force net production in rowing.

The results of the average force during the active phase to maximum force ratio in this study (*Table 6*) are in support of the observation that elementary rowing technique improved under the influence of practice sessions. A significant correlation ($r=0.48$, $p<0.01$) between blade efficiency and average force to maximum force ratio has been observed in previous studies (Kleshnev, 1995). The change in this ratio confirmed the transformation of the real-time force curve from the curve with a characteristic peak into the trapezoid curve (Zatsiorsky and Yakunin, 1991).

The increase in values of average speed during the active phase and of maximum speed under the influence of rowing practice (*Table 7*) was expected as all directly proportionate variables increased (STR LENGTH, POW AVRt, POW AVRa, POW PEAK) while inversely proportionate ones decreased (ACT TIME and FOR AVRt, FOR AVRa, FOR PEAK).

Both speeds (SPEED AVRa and SPEED PEAK) increased under the influence of learning the rowing technique. This was expected as the velocity of the boat was directly proportionate to the length of handle movement and the rowing frequency. The increase in the length of handle movement and the assigned rowing frequency led to increased handle velocity (Celentano et al., 1974). In earlier studies, a significant positive correlation ($r= 0.66$) was found between stroke rate and average velocity in the US Olympic eight, even the registered stroke rates were 37-41 str/min (Martin and Bernfield, 1980). Assigned rowing frequencies create situations where barriers that could be created as limitations for any further increase of rowing speed were not reached. This could be important evidence that the assigned frequencies were chosen correctly for the purposes of exploring the learning of the rowing technique. In rowing competition, high speed is a more significant parameter then low speed variability, since effectiveness is always more important than efficiency (Kleshnev, 1998).

An approximate optimum length of handle movement could be set at 164 cm – if we disregard the recommendations to define the length of a stroke by an angle (Mazzone, 1988; O´ Neill, 2003; Redgrave, 1995; Richardson, 2005) and the differences in styles such as "Adam Style", "DDR Style", "Rosenberg Style" and "Grinko Style" (Klavora, 1976; Kleshnev, 2006) which differ based on the amplitudes of moving the seat and the forward or backward incline of the body – considering that the mean value of the angle of the initial and final positions of the inner lever arm of the oar is approximately 90° and the length of the inner lever arm of the oar is 116 cm. The angles of the oar in reality vary from 80-85° for novices and 85-90° for experienced sweepers, and from 85-100° for novices and 95-110° for experienced rowers in sculls (Fenner, 1997). During the final measurement, the length of the handle movement deviated slightly from this optimum value (*Table 8*). Moreover, the self selected stroke length is very much a function of the physique of the participants (Dimakopolou t al., 2007).

It should be noted that the length of the handle movement is a consequence of the change of the angles of the initial and final positions of the inner lever arm and of the joints that make up a kinetic stroke cycle (O´ Neill, 2003; Redgrave, 1995). The changes in and superposition of the kinetic chain and handle movement in one final point, with a tendency to create a clear algorithm and connection on a timed scale of rotation and translator movement in learning a rowing technique, will be explored by research using an electro-goniometrical method (Hawkins, 2000) in the future. This is important because previous studies showed that patterned (movements made to recreate specific configurations of body parts) and positional (movements to targets external to the body) movement elements of well-practised everyday motor tasks, which involve a complex interaction of two types of movement, are controlled separately and place dissociable demands on the working memory (Woodin, 1996).

The increase in the length of the handle movement under the influence of the increased assigned frequency was expected. Experience shows that novice rowers did not understand the difference between changing the value of one technical parameter and changing the values of a number of technical parameters.

The finding that temporal variables described homogenous sets at the initial and final measurement was expected due to the fact that the criterion variable was also a temporal variable (FRQ). Somewhat higher values of the variation coefficient were noticed for rhythm, since the rhythm was affected by the duration of the active phase and the passive phase of the stroke (*Table 9*). In the temporal variables, a slight increase was observed in the variation coefficients at the final measurement. Although this was not expected, it could be explained by a considerable increase in the variables of the power and force of the stroke, as well as in the stroke variables concerning velocity and space. From the viewpoint of practice, significant improvement in learning temporal variables, such as the duration of active and passive phases of the stroke and stroke rhythm, should be expected at a later stage when the rowing technique has already been fully acquired.

The shorter duration of the movement (Ishikawa et al., 2005), the more successful its technical performance. The participants were more successful in technique performance at the final measurement than the initial one, which is reflected in the fact that the active phase of the stroke was shorter at the same rowing frequency. The decrease in the variation coefficient for the temporal variables was expected to take place with the increase of rowing frequency. In instances of precise time reproduction, this is explained by a linear increase of standard departures as the movement duration increases. Slower movements are inconsistent (Ishikawa et al., 2005). Also, the increase in rowing frequency resulted in the increased efficiency of the stroke (Kleshnev and Kleshneva, 1995; Lisiecki and Rychlewski, 1986; Sanderson and Martindale, 1986).

At the initial and final measurement, the variation coefficients of power and force (POW AVRt, POW AVRa, POW PEAK, FOR AVRt, FOR AVRa, FOR PEAK) had higher values compared to the other measured variables (*Table 9*). Previous studies confirmed that peak force variability decreased by the influence of practicing rowing (Lay et al., 2002). A decrease in the variation coefficient for power and force variables with the increase in rowing frequency was expected since slower movements are less consistent (*Table 9*). This phenomenon may be explained by smaller fluctuations in boat velocity during one cycle of the stroke (Kleshnev and Kleshneva, 1995; Sanderson and Martindale, 1986). With the increase in rowing frequency to the borderline value, the fluctuation of velocity, which is expressed in percentages, decreases compared to the average velocity (Celentano et al., 1974).

Changes in the values and variability of the variables are indicative of relatively fast improvement in the initial stages of learning the rowing technique; however, considering that power and force increase precipitately throughout a rower's carrier, the variables of the power and force of the stroke could be singled out as most sensitive to the changes induced by different factors (a break in practicing, waves, wind and others). As there is no direct proof to substantiate this assumption, it should be investigated in a future study. Because of the frequently rising values of power and force in novice rowers, frequent fine tunings and rigging should follow the size, strength and proportions of rowers (Fenner, 1997), as well as the levels of power and force (Baudoin and Hawkins, 2002). The rowers with properly rigged boats advance faster in learning the rowing technique, which is why some rowing experts believe that a properly rigged boat is more important to the learning process than coaching (Nolte, 2005a). Other findings of earlier studies emphasized that factors important for crew coordination in rowing include good synchronization, similarity of force-time profile and a common periodicity in the cycle of activity produced by each crew member (Wing and Woodburn, 1995), specially through the equalized and optimized contraction speeds of relevant muscles (Baudoin and Hawkins, 2002).

Ideal technique eliminates oscillations in boat velocity and maintains constant boat velocity during each stroke. The amplitude of boat velocity fluctuations is one of the most important factors in the rowing performance (Dal Monte and Komor, 1989). Low variation coefficients for velocity variables were expected (*Table 9*) since the handle velocity was directly proportionate to the assigned frequency and also to the distance traveled during the stroke cycle (the length of the handle movement in our case), which was limited by the rigging and the initial and final angles of limbs. The results of our research correspond to the rules of dependence of velocity on stroke frequency (Celentano et al., 1974). Higher absolute values of power and force also contribute to a decrease in the variability of speed. It was concluded that boat velocity fluctuations require greater propulsive force to maintain a given average system velocity than if the velocity was kept constant (Baudoin and Hawkins, 2002). The decrease in the variation coefficient of velocities with the increase in rowing frequency was expected. Average minimum shell velocity for the US Olympic eight in all the assigned frequencies deviated -24.4% from the mean velocity while the average maximum velocity deviated + 18.6% (Martin and

Bernfield, 1980). It has also been found that a higher stroke rating leads to smaller oscillations in the system velocity of rowing (Baudoin and Hawkins, 2002).

Low values of the variation coefficient of the length of handle movement in the initial and final measurements were expected (*Table 9*) as the values of handle movement length were limited, on the one hand, by the maximum amplitude of the movement and, on the other, by the assigned rowing frequency. The decrease in the variation coefficient with the increase in assigned frequency was expected.

The decrease in the variation coefficient with the increase in the assigned rowing frequency in all of the variables (Celentano et al., 1974; Kleshnev, 1995; Lisiecki and Rychlewski, 1986; Sanderson and Martindale, 1986) was confirmed in practice. Technique is learned and mistakes are corrected at lower frequencies, as the mistakes are more noticeable. Preparing for competitions at a later stage, rowers practice at frequencies that are similar to regatta frequencies.

Accidental changes in the control group showed that improvements in the experimental group happened under the influence of learning rowing technique.

The principal goal of the additional studies would be to set the norms and national standards for stroke parameters and define batteries of standardized tests to be used for studying rowing biomechanics on dry surface and in boats.

It should be stressed that the results of the measurements conducted during trainings, tests and competitions must be disclosed to rowers, irrespective to their level of performance. By revealing biomechanical data to novice rowers, especially at theory trainings, we could influence their understanding of rowing movements, the specific feel they get, conclusions they make about the rowing technique and the verbalization of their experience in the process of motor learning. While some rowers need figurative descriptions, others prefer technical specifications. Biomechanical feedback for athletes and coaches could be combined to fill the gap between the ideal technique in biomechanical terms and the conceptual world of the rower (Lippens, 2005).

5. CONCLUSIONS

Using the twelve-oared school boat *galley* – a boat with a large mass and high hydrodynamic resistance – is disadvantageous for learning the duration of active and passive phases of the stroke and the rowing rhythm. These disadvantages became advantages when learning the temporal pattern of intensity of stroke power and force.

The results of the final measurement show that stroke length was learned properly, indicating that it is an easiest element to learn.

The biggest improvement was noted in the power and force of the stroke, which also points to the improved relationships within a kinetic cycle established during rowing.

The frequency of rowing has been proven to be an important factor in learning the rowing technique. The learning process should start at a low frequency, which should change soon to 32 str/min.

The results of this study show that faults in rowing technique can be discussed at the level of variability of tested stroke parameters. Knowing these values could help come up with appropriate methods of learning the rowing technique in the early stages. Also, it should be emphasized that the rowing ergometer offers no possibility of the automatic calculation of stroke variables consistency. The benefits of observing this consistency could be improved by real time feedback.

The experiment has proven it is possible to explore the processes, phases, programs and methods of motor learning through the evaluation of initial, interim and final absolute values of kinetic variables of the stroke, especially of their variability. A logical next step after this study would be to make a plan for the systematic development of biomechanical variables, which would include objectives and key outcomes for each stage of training.

The analysis of the results of learning the rowing technique could raise an issue of whether there is a clear borderline between learning and training, and what their key elements are. These elements seem to be the adaptation and disruption of adaptation, resulting in resetting to a higher quality level of rowing technique.

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PROCENA UČENJA VESLAČKE TEHNIKE U ŠKOLSKOM ČAMCU GALIJA SA 12 MESTA

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Ovom studijom istražen je uticaj učenja veslačke tehnike u školskom čamcu „Galija" sa dvanaest mesta na varijable zaveslaja. Eksperiment je realizovan na uzorku od 44 studenta Fakulteta Sporta i fizičkog vaspitanja, bez prethodnog veslačkog iskustva, starosti 25,34±1,95godina, TM 81±8kg i TV 184±7cm. Ispitanici su učili osnovnu veslačku tehniku u školskom čamcu sa 12 mesta „Galiji". Časovi učenja su organizovani tri puta nedeljno u toku deset nedelja. Za prikupljanje osnovnih podataka na inicijalnom i finalnom merenju, korišćen je CONCEPT II veslački ergometar. Za merenje varijabli zaveslaja u realnom vremenu korišćen je instrument FITRO ROWER firme WEBA Sport. Ispitanicima nije sugerisano kakvu distribuciju sile i dužinu zaveslaja da upotrebe. Praćeno je trinaest biomehaničkih varijabli zaveslaja uključujući vremenske varijable, varijable sile i snage, brzinske varijable i prostornu varijablu. Test se sastojao iz tri merenja sa zadatim tempom od 24, 28 i 32 zav/min u trajanju od 30 sekundi. Do značajne promene došlo je kod svih prediktorskih varijabli. Rezultati u finalnom merenju su pokazali da je pređeni put rukohvata varijabla koja je prva naučena. Najveći napredak u apsolutnim vrednostima ali i najveće smanjenje koeficijenata varijacije zabeleženi su kod varijabli sile i snage. Dokazano je da je tempo veslanja značajan faktor pri obučavanju veslačke tehnike. Obuku treba početi sa manjim tempom, a ubrzo preći na tempo od 32 zav/min. Rezultati pokazuju i da se o greškama u veslačkoj tehnici može govoriti i na nivou varijabilnosti testiranih varijabli zaveslaja.

Ključne reči: *WEBA, CONCEPT II, tempo, sila, dužina zaveslaja.*